to severe co-morbidity. Stereotactic body radiotherapy (SBRT) has been used for treatment of patients with limited stage NSCLC who are unfit for surgery.
Methods and materials: Forty patients with stage I NSCLC were included into a phase II trial. The patients were immobilized by the Elekta stereotactic body frame (SBF) or a custom made body frame. SBRT was given on standard LINAC with standard multi-leaf collimator. Central dose was 15 Gy × 3 within 5–8 days.
Results: Median follow-up time of the patients was 2.4 years. Eight (20%) patients obtained a complete response, 15 (38%) had a partial response and 12 (30%) had no change or could not be evaluated. Only 3 patients had a local recurrence and local control rate two years after SBRT was 85%. Two years after treatment, 54% were without local or distant progression and overall survival was 47%. Within 6 months after treatment, one or more grade 2 reactions such as chest pain, skin reaction, increased used of analgesics, dyspnoea and deterioration in WHO performance status to 2 or higher was observed in 48% of the patients. Sixty-two percent and 63% of the patients experienced transient or permanent deterioration in lung function (grade > 1) or performance status (WHO > 1) during follow-up.
Conclusions: SBRT in patients with limited stage NSCLC results in high probability of local control and promising survival rate. The toxicity after SBRT of lung tumours is moderate. However, deterioration in performance status and respiratory insufficiency are observed.

1426 POSTER

Patterns of failure: following intraoperative radiation therapy and stereotactic radiosurgery for glioblastoma multiforme on magnetic resonance appearance

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Purpose: The purpose of our study was to evaluate the Magnetic Resonance (MR) appearance of the patterns of failure following Intraoperative Radiation Therapy (IORT) and Stereotactic Radiosurgery (SRS) for Glioblastoma Multiforme (GBM).
Method/Materials: From January 1982 to June 2003, 137 GBM patients underwent radiotherapy. From January 1982 to August 2000, 53 patients were selected for IORT. Of those patients, 22 patients were excluded from the study because enhanced MR imaging examinations were not performed before or after IORT. The remaining 31 patients were included the study population. All 31 patients had undergone tumor debulking confirming the diagnosis of GBM and received conventional external beam radiotherapy (30–57 Gy, mean 53.4 Gy) excluding 3 patients. From September 2000 to June 2003, 25 consecutive patients underwent SRS. All patients underwent enhanced MR imaging examinations before and after SRS, and had undergone tumor debulking confirming the diagnosis of GBM and received conventional external beam radiotherapy (38.4–60 Gy, mean 44 Gy) excluding 2 patients. Finally, 31 patients of IORT and 25 patients of SRS formed the study population. The radiation field of IORT was determined to affect a level of 2–6 cm deeper than the tumor-resected surface. The energy of the beams ranged 7 to 22 MeV (mean 11 MeV) depending on the estimated tumor depth. Irradiation in IORT was 10–50 Gy (mean 26.7 Gy). SRS was performed using a 10-MV linear accelerator. The planning target volume was the gross tumor (enhanced area on MR imaging) with 2 mm margin. The central dose was 20–30 Gy (mean 26.4 Gy) and marginal dose was 15–25 Gy (mean 20.8 Gy). After IORT or SRS, follow up gadolinium-enhanced MR images were obtained every 1–3 month. Recurrent patterns were classified into six patterns on MR images (local area within edema [1: focal, 2: semicircle, 3: circle, 4: no continuity to initial tumor], distant area [5: without edema, 6: local area + without edema]). As to the direction of the recurrence, recurrent patterns were classified into two patterns on MR images (1: including the direction to the cerebral ventricle, 2: the other).
Results: The progression free period of IORT was 6.1 months and that of SRS was 7.1 months. The progression free period of gross tumor resection was significantly ($P < 0.05$) longer than that of subtotal resection and partial resection in IORT, and was significantly ($P < 0.05$) longer than that of partial resection in SRS. As to recurrent patterns of MR images, local area within edema pattern was significantly ($P < 0.05$) seen both in IORT (84%) and in SRS (76%) than distant area pattern. Of local area within edema pattern, circle pattern was more predominantly seen 10 patients (38%) in IORT and 10 patients (53%) in SRS. As to the direction of the recurrence, all patients were including the direction to the cerebral ventricle both IORT and SRS.
Conclusions: The recurrence pattern of failure seems similar to the recurrence pattern of the conventional radiation therapy on MR appearance. Irradiated field in IORT and SRS should be included the cerebral ventricle neighboring the GBM.

1427 POSTER

Fractionated stereotactic radiation therapy using cyberknife for primary liver cancer

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Purpose: There currently is not a standard treatment for inoperable small and advanced hepatoma. Conventional radiotherapy is playing the limited role of the application against hepatoma, which shows one of the cancers with high incidence in Korea. There is a few report to evaluate the response of the fractionated stereotactic radiotherapy (FSRT) or radiosurgery(FSRS) to primary hepatoma. The purpose of the study was taken the preliminary result on the clinical trial of primary hepatoma(small and advanced) by the CyberKnife, as a new FSRT(or Hypofractionated Radiosurgery)-system.
Materials and Methods: From March 2004 to March 2005, 114 patients were hospitalized in the CyberKnife Center of Catholic University Medical College, and treated with CyberKnife for extracranial tumors. Among them, 32 patients were diagnosed to primary hepatoma and then 33 lesions applied by the CyberKnife. There were 20 male and 12 female patients. They had the age of 47–78 year old (median: 57) and the tumor size of 5.4–156 cc (median 27.5 cc). The total doses administered were 30–39 Gy (median 36 Gy) to the 70–83% (median 75%) isodose curve for 3 fractions. To relive gastrointestinal trouble after treatment, we used Bermkain and Buscopan during cyberknife.
Results: Follow-up ranged from 1 month to 5 months with median of 3 months. After treating CyberKnife to 33 lesions of 32 patients with primary hepatoma, the response of the tumor was examined by abdominal CT: they are classified by ten complete regression (31.3%), 13 partial regression (40.6%), 6 minimal regression (18.7%), 3 progression disease (9.4%). The positive responses more than partial remission were 23 patients (71.9%) after the treatment. In advanced hepatoma with portal vein or inferior vena cava thrombosis, 2 patients of total nine patients showed complete regression (22.2%) and two patients minimal regression (22.2%). The level of serum alpha-fetoprotein (AFP) after the treatment as compared with pretreatment had been 55% (17/32) decreased. There was no severe treatment-related complication except dyspepsia (1), mild nauseas (6), abdominal discomfort (3) and transient changes of hepatic function(6). Two patients were died during the follow up due to hepatic failure with sepsis and progression of pre-existing lung metastasis.
Conclusion: CyberKnife to the patients with primary hepatoma was potentially suggested to become the safe and more effective tool than the conventional radiotherapy even though there were relatively short duration of follow-up and small numbers to be tested. And We expect CyberKnife become a new effective method for the management of advanced hepatoma with portal vein tumor thromboses(PVTT), inoperable and ineffective to transarterial chemoembolization(TACE).

1428 POSTER

Experimental model of radiation sequelae induced with single stereotactic irradiation to normal rabbit lung. Computed tomographical analysis

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Background: Hypofractionated stereotactic irradiation (HSTI) to treat early non-small cell lung cancer in Japan may be a possible alternative to surgical treatment. To examine the sequelae of HSTI treatment, we tried to establish an HSTI technique by irradiating normal rabbit lung and examining the radiation sequelae using computed tomography (CT) images.
Material and methods: Guidelines of the Keio University School of Medicine for the care and use of laboratory animals were followed in all experiments, and the use of rabbits was approved. Seven Japanese White Rabbits were anesthetized and partial spherical volume of each left lung was stereotactically irradiated with 4 MV of X-ray energy with a narrow beam of size 11 mm × 11 mm. Three non-coplanar arcs (couch rotation: 0 deg±45 deg) were employed for arc rotation. Each gantry rotation arc was 160 deg. The dose monitor units of irradiation were calculated by the standard inverse square law algorithm using the Batho Power Law as an inhomogeneity correction on the radiotherapy planning system (Eclipse®). Total irradiated dose of each rabbit varied and was 21, 30, 39, 48, 60, 60, 60 Gy, respectively. The doses of irradiation were estimated using two different dose calculation algorithms, Convolution and fast superposition. After the irradiation, each rabbit (while under general anesthesia) was scanned with a CT scanner approximately biweekly and the image data were collected as Digital Imaging and Communications in Medicine (DICOM) Standard files. All rabbits were examined for 24 weeks

after irradiation. The images were analyzed visually on a DICOM viewer. Round regions of interest, corresponding to the stereotactically irradiated area and the comparable part of the contralateral lung were delineated on CT images. The ratio of CT values (irradiated part to comparable part of the contralateral normal lung) was calculated for each scanned rabbit lung image. Additionally the ratio after irradiation was divided by the ratio before irradiation and used to compare seven time course variations under the same conditions.
Results: Against expectation, slight changes in the irradiated lung were observed. Localized attenuating opacities suggesting emphysematous change appeared consistently in the irradiated parts of several rabbits 7–14 weeks after irradiation. The findings persisted after the first visualization. In only one rabbit, a localized consolidation was visualized, but the finding vanished in two weeks. The time course curve of the ratios was variable and indicated no significant regularity.
Conclusions: Though the single dose of stereotactic irradiation was high, the sequelae were subtle. At this time, the reason is unclear. Rabbit lung might be more tolerant to acute and subacute radiation effects than human lung.

1429 POSTER

A new collimator insert system for stereotactic irradiation of intracranial lesions

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Background: The objective of this study was to develop a prototype linac-based stereotactic irradiation system for clinical use. All dosimetric parameters were measured in order to be implemented in the Treatment Planning System.
Material and Methods: A new collimator insert system was designed and developed to simulate stereotactic irradiation. 3 cones made of alloy were constructed and mounted to the gantry head of a Siemens MX 6 MV linac to produce circular fields from 1–2.5 cm in diameter. Collimator concentricity test was performed to ensure that the central axis coincides with the isocentre of the treatment unit. Multi profile measurements were made for each cone, along with PDD calculations and other beam parameters such as TMR, off-axis ratios and output factors, to implement in a TPS. For in vivo verification of the planned dose distribution TLD-100 rods and Kodak EDR-2 films were used in a humanoid phantom.
Results: Collimator concentricity test showed a variation of not more than 0.5 mm, which is acceptable for Stereotactic Radiotherapy. All dosimetric parameters examined demonstrate high accuracy in dose distribution for each one of the developed stereotactic cones. Non-coplanar arcs of various angles were performed to indicate that the absorbed dose of organs at risk was in good agreement compared to the dose provided by the TPS.
Conclusions: High reliability and reproducibility of the proposed treatment process was illustrated, in terms of accuracy and dose calculation precision. The treatment of intracranial lesions demands the ability to deliver the necessary dose in a narrowly collimated beam. As a result this method can be clinically applicable when irradiating an intracranial lesion.

1430 POSTER

Analysis of application X-ray radiation up to 250 kV for stereotactic radiosurgery and radiotherapy

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Background: X-ray radiation, when delivered from many directions, seems can be in competition to high energy radiation sources in the case of small targets. To confirm this thesis X-ray device design was proposed and numerical analysis of dose distributions in typical for stereotactic radiation was performed.
Material and methods: X-ray radiation heads with energies 60, 150, 225 kV, and Co-60 point collimated source were simulated Using Monte Carlo code EGS4/Nova. Particle fluency spectra and angle distributions were analyzed and radiation source models, suitable for routing Monte Carlo treatment planning, were created. Dose distributions in the phantom, representing human head with 25 mm diameter asymmetrically located target and 10 mm thickness spherical bone ring, were simulated by Monte Carlo method. As a first step 60 kV X-ray treatment machine, capable to move radiation source along conical trajectory and using wedge filters for dose uniformity, was built. Experimental dose distributions were collected for numerical calculations verification.
Results: Dose distributions in the target vicinity. Bone structure collects high dose at smaller energies. This prevents low energy X-rays application in the presence of bones. At energies 150 kV and high spectrum filtration absorbed dose bone / soft tissue ratio drops to acceptable level. Average dose in normal tissues far a way from target almost do not depend on X-rays energy and is approximately two times higher than in high energy photons, but steel at the acceptable level. In the case of target location near the body surface and especially in lung X-rays have dosimetry advantages. Additional advantages X-rays may have in the presence of radiomodifiers, like high atomic number elements, incorporated in the target. Comparison of Monte Carlo calculations with experimental data for 60 kV radiation unit show agreement within experimental accuracy. At the present time micro MLC for X-ray unit and treatment planning system are in the process of development.
Conclusions: For targets up to 3 cm in diameter X-ray radiation is comparable to high energy radiation sources. Possible application could be treatment of brain diseases, lung metastasis, liver and other targets, located near body surface. Bones, located near the treatment volume restrict X-rays application.

1431 POSTER

Measurement of the exposure dose to the phantom's body for LINAC-based stereotactic radiosurgery

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Introduction: LINAC-based stereotactic radiosurgery (SRS) is an effective therapy not only for malignant tumors, but also for benign tumors or benign disease like AVMs. Therefore, young patients are often treated by SRS. Because non-coplanar beams are used, it is expected that the exposure dose to the patient's body, especially the embryos of pregnant women, is larger in cases of SRS using LINAC than in cases of conventional radiotherapy for intracranial lesions using coplanar beams. We measured the exposure doses in phantom cases and investigated the safety of this treatment in terms of radiation exposure to pregnant women.
Methods: An intracranial point of the human-body-phantom was determined to be the isocenter, and we shot 90-degree rotary irradiation into the isocenter using narrow bean collimators with diameters of 1.25 cm and 4.00 cm. We performed rotary irradiations from 0- to 90-degrees and from 90- to 180-degrees of the gantry rotation, with couch rotations of 0-degrees and 90-degrees. We set a dosimeter on the navel of the phantom and evaluated the exposure doses, first using a 450 MU (5MU/degree) and second using a 900MU (10MU/degree) to the isocenter. For each case we measured the exposure doses three times, and calculated the average.
Results: When shooting 450MU using a 1.25 cm collimator and 0-degree of rotation of the couch, the mean exposure doses on the navel of the phantom with gantry rotations of 0-degrees to 90-degrees and 90-degrees to 180-degrees were 1.32 mGy and 1.26 mGy, respectively. When the couch was rotated 90 degrees, the exposure doses were 4.69mGy, and 4.14mGy, respectively. The exposure doses were 1.2–1.7 times greater when using a 4.00 cm collimator than when using a 1.25 cm collimator in cases in which the couch was rotated 0-degrees. On the other hand, when using a 4.00 cm collimator, when the couch was rotated 90-degrees with 90-degrees to 180-degrees of gantry rotation, the exposure dose was 13.6 mGy, which was 10.8 times greater than when using a 1.25 cm collimator, with the couch rotated 0-degrees with gantry rotations of 0-to 90-degrees. When shooting 900 MU, the exposure doses increased twice as high as when shooting 450 MU.
Conclusions: The exposure dose on the navel was high when the couch was rotated 90-degrees, especially when using large collimators. For treating patients, sometimes more than 450 MU per arch is given. If treatment planning for pregnant women includes 2 arcs with a couch rotation of 90 degrees and −90 degrees, the exposure dose to the embryos may exceed tolerable levels.

1432 POSTER

Hypofractionated stereotactic radiotherapy alone without whole-brain irradiation for patients with solitary and oligo brain metastasis with diameter more than 3.5 cm: a feasible and efficacy alternative

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Purpose: Efficacy, toxicity evaluation of hypofractionated stereotactic radiotherapy (HSRT) using noninvasive fixation of skull on solitary or oligo brain metastatic patients as an alternative to whole brain radiotherapy.
Patients And Methods: The subjects were 24 patients who had 3 or fewer brain metastases (18 solitary, 6 oligometastases)with maximum diameter